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The Influence of Localized Winds on Arctic Freshwater and Heat Export

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-Special thanks to Xianmin Hu for technical support.
-We are grateful to Gregory Smith for the CGRF forcing data.
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Motivation

- Bursts of intense wind can enhance air-sea heat exchange
  -> Trigger deep or intermediate convection [1]
  that impacts:
  1. nutrient distribution and chemical exchange [2]
  2. Atlantic Meridional Overturning Circulation (AMOC) [3]
- as the climate warms storms are predicted to increase [4]
- How do bursting winds affect the transport of heat and freshwater out of the Arctic?

Bursting winds:
storms, barrier winds, cold air outbreaks, polar lows, topographic jets

Ocean-Ice Model

- NEMO -Nucleus for European Modeling of the Ocean [5]
- Arctic Northern Hemisphere Atlantic Configuration
- LIM2 - Louvain-la-Neuve Sea Ice Model (LIM)
- 1/4° grid
- 50 vertical levels

Atmospheric Forcing

- CGRF-Canadian Meteorological Centre's Global Deterministic Prediction System [7]
- hourly atmospheric data (2002-2014)
- Resolution: 0.45° longitude, 0.3° latitude
- model forecasts from operational analysis

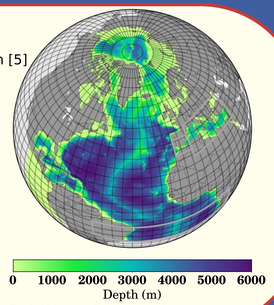

Fig.1: Model configuration and bathymetry.

Transport Validation

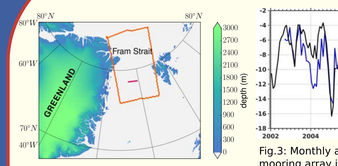

Fig.2: Locations for mooring array (pink) and regional mask (orange).

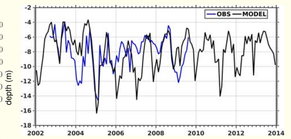

Fig.3: Monthly averaged volume transports from a mooring array in the East Greenland Current [8] plotted with the equivalent section in the model.

Correlation	Mean Values
0.47	data: -8.16 Sv model: -8.056 Sv

Filtering the Atmospheric Forcing

- wind and temperature fields were filtered using a moving average filter [6]
- time scales less than one week were removed

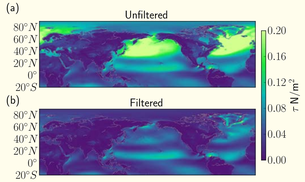

Fig.4: Wind stress.

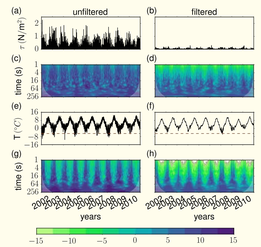

Fig.5: Wavelet spectrogram of filtered and unfiltered data.

Bursting Winds Influence Arctic Transports

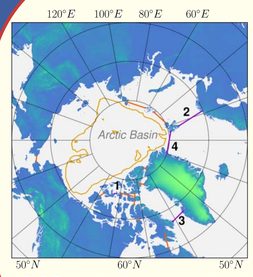

Fig.6: Transport sections (orange and purple (shown)) and the Arctic region used to compute Heat content (yellow).

The CAA

1. Lancaster Sound

Eurasian Basin

2. Barents Sea opening

Baffin Bay

3. Davis Strait

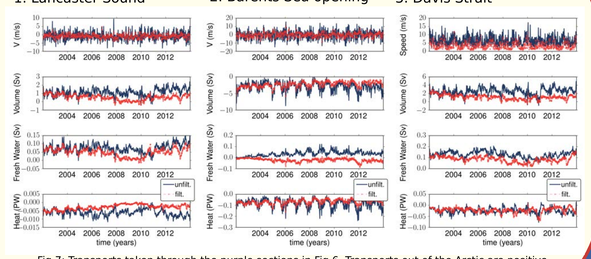

Fig.7: Transports taken through the purple sections in Fig.6. Transports out of the Arctic are positive.

Bursting winds:
- enhance southward transport of freshwater
- play a role in heat transport into the Arctic

Heat Content in the Arctic

1. Over the Entire Depth

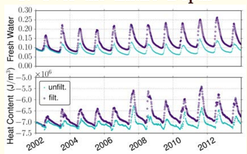

Fig.8: Averages taken within the Arctic basin (yellow curve in Fig.6).

2. In the Mixed Layer

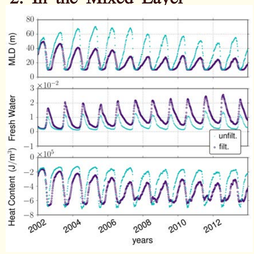

Fig.9: Averages taken within the Arctic basin (yellow curve in Fig.6). We normalize by the depth of the mixed layer.

Bursting winds:
1. • decrease the FW content
   • lead to a colder Arctic Basin
2. • deepen and warm the mixed layer
   • over time the difference between the two simulations increases

Fram Strait

What was removed by the filtering?

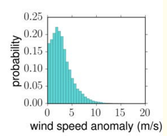

Fig.10: Averaged over the orange rectangle in Fig.3

The wind speed anomaly calculated as the difference between filtered and unfiltered winds.

Filtered vs unfiltered

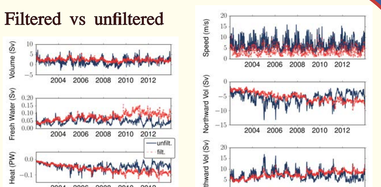

Fig.11: Transports taken across the yellow line marked 4 in Fig. 6. Positive indicates southward flow.

Bursting winds:
- inhibit transport of freshwater out of the Arctic
- increases the southward flow of heat

Directional Constancy

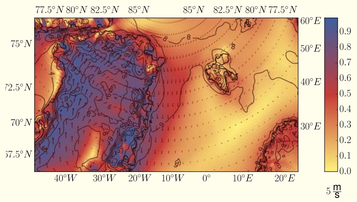

Fig. 12 Winter climatology of the CGRF 10 m winds North of Greenland from 2002 - 2010 (DJF). With sea level indicated in black the color-map shows the directional constancy (DC) of the wind, dark contours are labelled with the scalar averaged wind speeds, and mean wind vectors are plotted on top.

A directional constancy near one implies that the wind tends to flow in a single direction

$$DC = \frac{\bar{S}v}{\bar{S}} = \frac{\sqrt{\bar{u}^2 + \bar{v}^2}}{\sum_{i=1}^{N} \sqrt{u_i^2 + v_i^2}}$$

- the wind tends to flow southward
- northward moving storms may affect transports
- strong topographically accelerated flows enhance the downward heat flux.

Gale Force Wind Events in Fram Strait

Criterion for an event:
- events begin when wind speeds exceed 17 m/s for at least 6 hours anywhere in the study region shown in orange in Fig.3.
- An event ends when winds are below 17m/s for at least 3 hrs
- there are 24 hrs between events

- Volume and freshwater transports were computed through the yellow section in Fig. 2.
- We found the relative difference between the transports occurring during an event and the average over the month in which the event occurred.

Gale force wind events can strongly enhance transports and reverse the direction of flow

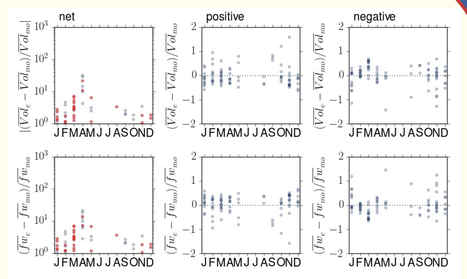

Fig.13: red markers indicate that the direction of transport during the event is opposite to the monthly average.

Summary

Bursting winds ...
- significantly impact the transport of freshwater out of the Arctic
- Influence the heat content of the Arctic basin

Future directions and unanswered questions:
- Bursting winds bring warmer waters northward and mix warmer surface waters leading to a warmer mixed layer, but why/how do they cool the Arctic basin?
  1. separate the impacts of different winds (cyclones vs. tip jets etc.)
  2. analysis of transports at various depths
  3. examine ssh and dynamic heights for each of the straits
  4. examine FW pathways
- In the CAA, the Eurasian basin and around Baffin bay bursting winds enhance FW exports, but these winds can inhibit FW export through Fram Strait.
  1. separate the impacts of different winds (cyclones vs. tip jets etc.) ->self-organized maps
  2. analysis of transports at various depths

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